DOE/ER/63074

Final Report for DOE Contract: DE-AI02-01ER63074

Title: Assessing the Importance of Using Bimodal Size Distribution for Ice Cloud Optical Property Parameterizations.

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Work Summary:

This report represents the final report for DE-AI02-01ER63074. This work represented some follow-on work to that completed under DE-AI02-01ER62669. The research reported here is undertaken in collaboration with Dr. David Mitchell of the Desert Research Institute in Reno, Nevada. The progress given here represents my contribution to his approach by providing radiative transfer expertise and calculations.

Continuation of Spectral Cirrus Radiative Properties in the Thermal Infrared

Last year's results focused upon the broadband thermal infrared spectrum (3.82 - 500 um) and contrasted the magnitude of the difference between bimodal and exponential size distributions. The sensitivity to the assumption of no scattering was assessed. For example, the Outgoing Longwave Radiation (OLR) relative to assuming no scattering for bimodal size distributions was reduced by 8 W m^-2 for an effective size of 60 um and ice water path (IWP) of 10 g m^-2. This bias is diminished as optical thickness and particle size are increased with maximum biases for the smallest effective particle sizes. The assumption of "no scattering" using an exponential size distribution showed relatively little sensitivity. Therefore, the difference in the broadband radiative properties was due mostly to the difference between using the bimodal and exponential size distributions to represent the cirrus cloud and the nonscattering assumption added additional error. This year we analyze the effects of the bimodal size distributions relative to exponential size distributions in terms of the wavelength dependence of the radiative properties. This is accomplished by partitioning the thermal infrared spectrum into broadbands (i.e., near-ir, window, and far-ir) and looking at the contribution of each band to the emittance, and heating/cooling rates and OLR for varying IWP and effective particle sizes. The assumption of "no scattering" will also be assessed spectrally. Climate implications will be discussed.

Surface Radiation Budget Over ARM CART Site

We expect the treatment of cirrus cloud properties also effect the amount of energy transmitted to the surface and subsequently measured by ARM radiation measurements. In this extended proposal we began to work towards assessing this impact by beginning to develop ties of the cirrus work to the Global Energy and Water Cycle Experiment (GEWEX) Surface Radiation Budget Project (SRB). The work summarized here was funded partially from the NASA funding of this project. The GEWEX SRB uses top-of-atmosphere (TOA) radiance measurements and cloud property retrievals to estimate

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surface fluxes on a global basis. Normally, GEWEX SRB algorithms rely on TOA radiances and cloud information derived from International Satellite Cloud Climatology Project (ISCCP) data. Here, we show first results of using SW and LW algorithms featured in the GEWEX SRB data sets to derive estimates of surface fluxes using the ARM GOES-8 cloud and radiative properties data set. The ARM GOES-8 data set is derived using the Layered Bispectral Threshold Method (LBTM, see Khaiyer et al., 2001 this conference). The surface fluxes are computed for the domain from 32 degrees N - 42 degrees N and 91 degrees W - 105 degrees W at 0.5x0.5
degree resolution centered over the ARM Southern Great Plains Central Facility. Experimental results for a few cases are shown and compared to surface measurements where applicable. This work is being explored with the goal of adding gridded surface radiative fluxes to the list of ARM operational products.

- Demonstrated the application of GEWEX SRB algorithms for using GOES-8 ARM satellite observations over the ARM CART Site region
  - SW clear-sky surface downwelling on average is underestimated for general algorithm by 34 W m^{-2} (note: broadband hemispheric give averaged fluxes 17 W m^{-2} smaller); adjustments for aerosols according to MFRSR measurements reduce the bias to less than 1 W m^{-2}.
  - SW clear-sky surface upwelling underestimated (surface albedo too low compared to observations) by 38 W m^{-2}. Although aerosols can account for about 10 W m^{-2}, further analysis shows that observed broadband TOA clear-sky albedo is lower than the surface albedo implied by observations. Therefore, the algorithm physics cannot account for differences, but these factors are likely:
    - differences between albedo of site area vs. grid box area
    - VIRS calibration/ERBE ADM errors (precipitation previous 2 days could have reduce ADM relative to general land)
  - SW cloudy-sky biases will be scrutinized more closely, but SW down RMS is dominated by outlier occurring on grid box and cloud boundary (note: broadband hemispheric give averaged fluxes 9 W m^{-2} smaller). An adjustment for the thermal offset has been performed to the measured diffuse flux, but the uncertainties are not known. These are not atypical of instantaneous spatially averaged estimates compared to time averaged measurements in cloudy-skies.
  - LW clear-sky biases easily within instrument uncertainty of 5 W m^{-2}
  - LW cloudy-sky biases imply too warm a skin temperature of approximately 5 K. A preliminary comparison to the ARM CART site reveals a 6 K difference between the observed surface and retrieved skin temperature under thick cloud conditions.

- Future Work:
  - More validation and testing vs. GOES-8 ARM retrievals and the ARM CART site and extended facility observations is required
  - The results here point to the following issues for more
    - Surface albedo: understand SW up measurements?
    - Regional aerosol properties: adjustments to model background aerosols
    - Skin temperature vs. air temperature under cloudy conditions

- Conversion of algorithms to quasi-operational
- Reprocessing of ARM IOPs

Retrieval of Cirrus Cloud Properties Using Thermal Channels

Collaborated with study of D. Mitchell and R. P. d'Entremont by searching through selected portions of ISCCP and ARM GOES data to help find cases to test the retrievals using the newly developed ice optical property fields. Collaborated on producing the ultimate poster.

Papers and Products

Posters without Abstracts:

Mitchell, D.L., R. P. d'Entremont, P. W. Stackhouse, Jr., A.J. Heymsfield, 2001: Retrieval of Ice Water Path Using Thermal Channels. Poster at the Eleventh Atmospheric Radiation Measurement (ARM) science team meeting, U.S. Department of Energy, March 19 to 23, Atlanta, Georgia.

Stackhouse, P.W., Jr., D. Mitchell, and P. Yang, 2001a: More on Effect of Cirrus Bimodal Size Spectra on Thermal Infrared Wavelengths. Poster at the Eleventh Atmospheric Radiation Measurement (ARM) science team meeting, U.S. Department of Energy, March 19 to 23, Atlanta, Georgia..

Stackhouse, P.W., Jr., S. K. Gupta, S. J. Cox, P. Minnis, W. L. Smith, Jr. and M. M. Khaiyer, 2001b: Using ARM GOES-8 Cloud and TOA Flux Properties to Estimate Surface Radiation Budget Parameters. Poster at the Eleventh Atmospheric Radiation Measurement (ARM) science team meeting, U.S. Department of Energy, March 19 to 23, Atlanta, Georgia..

Budget Report and Summary:

Description	Labor F.T.E. (months)	F.T.E. Cost (per month)	Total Cost Year 1
G&A (6% of $6,550)			$478.00
NASA Civil Servant Overhead – Program Support	1	$2166.67	$2,166.67
NASA Non-personal Contractor (full cost)	0.4 (8 days)	$7923.28	$3169.31
Travel (ARM Science Mtg. – Atl, GA)	-----	-----	$736.02
Totals	1.25	-----	$6550.00